BNL, NIST, Norway Gain New Insight into the Superconductivity of MgB_2

New insight into the superconductivity of magnesium diboride (MgB_2) has been recently revealed by a team of scientists from BNL, the National Institute of Standards & Technology (NIST), and the University of Oslo in Norway. The findings appear in the June 17, 2002 issue of *Physical Review Letters*.

The new information about MgB_2, an unusual superconductor discovered only last year, promises more understanding of superconductivity – the ability of some materials to conduct electricity without losing energy – which could lead to improved magnetic resonance imaging, more efficient electric power transmission, and smaller, more powerful electronic devices.

"Scientists usually assume that superconductivity arises from electrons coupling in pairs," said Yimei Zhu of BNL's Energy Sciences & Technology Department, lead author of the study. "Though this is the case for most superconductors, it has not been shown yet how electrons contribute to superconductivity in magnesium diboride." Therefore, the team decided to investigate this through research supported by DOE and DOC.

Since the discovery of superconductivity in MgB_2, BNL theoretical scientists, led by physicists James Davenport, Energy, Environment, & National Security Directorate, and Guenter Schneider, Physics Department, made extensive calculations involving interactions between electrons or between electron "holes," which are empty locations that could be filled by electrons.

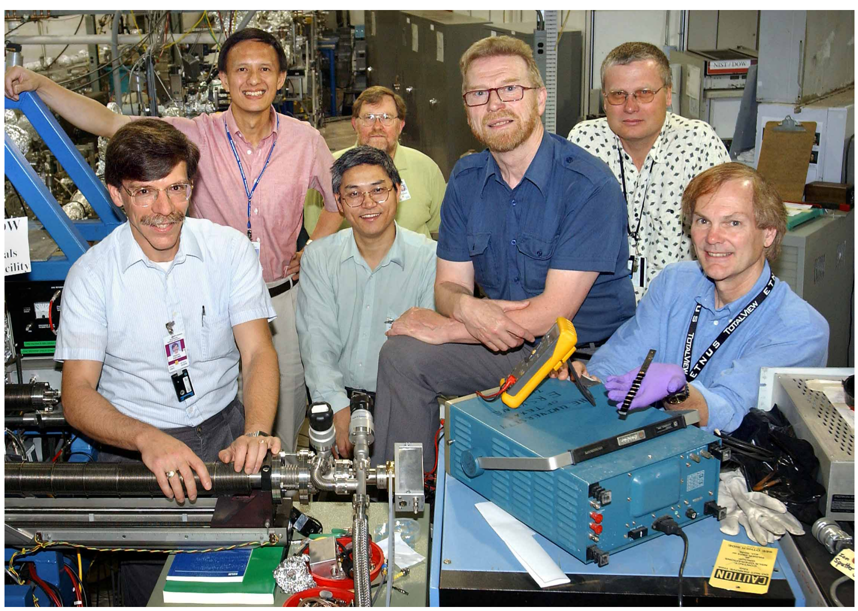
"Superconductivity in MgB_2 is expected to arise from interactions between holes," says BNL physicist Arnold Moodenbaugh, a member of the team. "Because MgB_2 is made of alternating planes of boron and magnesium atoms aligned parallel to one another, these holes are expected to interact more easily within the planes than between adjacent planes."

"Compared to other superconductors, MgB_2 has a relatively simple structure," says Johan Tafto, a physicist at the University of Oslo and another team member. "We hoped to get more insight into superconductivity by focusing on a simple compound rather than on more complex ones."

To test the theoretical predictions about MgB_2, the researchers used two complementary techniques: x-ray absorption spectroscopy and electron-energy-loss spectroscopy. In the first technique, very intense x-rays enter the sample and are absorbed by the electrons inside it. In this experiment, the electrons, which are ejected out of their original positions, are tracked in a unique x-ray detector, designed and built by NIST physicist Daniel Fischer and his team.

"When the ejected electrons fall into the holes, they reveal the number and density of the holes in the sample," said Fischer, who has worked with the x-ray absorption technique for the last 18 years at the NSLS.

The second technique uses state-of-the-art transmission electron microscopes (TEMs) at BNL. Unlike optical microscopes, which use visible light, electron microscopes project electrons toward the sample. These electrons transfer some of their energy to electrons in the sample, which bump around the sample atoms and reveal the



Near the NIST/Dow beamline U7A at the NSLS, where part of the MgB_2 study was conducted, are team members Daniel Fischer, Yimei Zhu, Genda Gu, Arnold Moodenbaugh (back), Johan Tafto, Tom Vogt and James Davenport. Absent from the photo are team members Guenter Schneider and Qiang Li.

positions of electronic holes in the sample.

"We needed to use both techniques because they complement each other so well," Zhu said. "They lead to a very accurate determination of the distribution and number of electron holes in MgB_2." The leader of BNL's TEM group at the Advanced Electron Microscopy Facility, Zhu has been investigating the electronic structure of materials at the nanoscale (one billionth of a meter) for the last 20 years.

By showing that interactions between holes in the boron planes do occur in MgB_2, and that superconductivity stems from such interactions, the scientists showed that results from both techniques agree with the theoretical predictions.

Said Tafto, "As we gain more understanding of the properties of MgB_2 at the atomic level, I am confident that, in the near future, we will be able to relate them to macroscopic properties such as superconductivity - and maybe explain the origin of superconductivity in general."

-Patrice Pages

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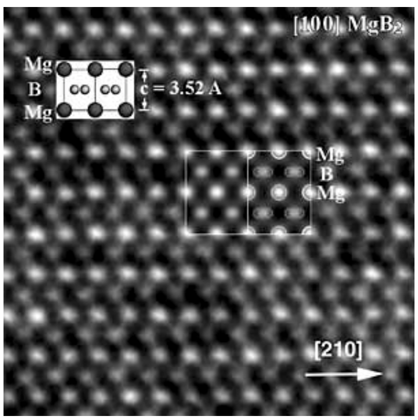
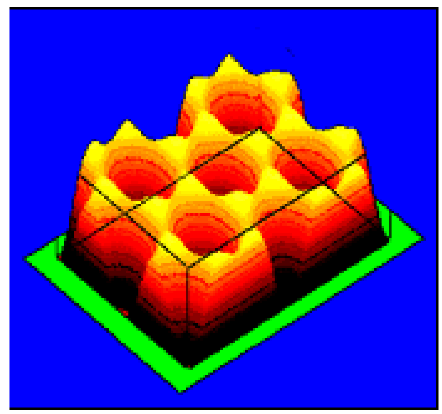


A plane of magnesium atoms (white spheres) above a plane of boron atoms (grey spheres) in MgB_2, as seen by the transmission electron microscope used in the study. The embedded image (top left) is a model of the structure, showing the expected positions of the atoms and the distance between two magnesium planes.



An illustration of the distribution of electrons between boron and magnesium atoms. Electrons cluster around the boron atoms (yellow peaks) and move away from the magnesium atoms (orange valleys).